Transformer bushings and oil leaks

A cost effective way to address oil and nitrogen leaks

ABSTRACT

Many oil-filled large power transformers have been in service for years. One issue with aging transformers is addressing oil leaks. This article describes a cost-effective technique for repairing these oil leaks. Repairs can be made without draining the oil, or removing bushings. Often the repairs can be made with the transformer in service. This article presents the techniques used by a company that has been performing leak repairs on electric substation equipment since 1988, and works exclusively on electric substation equipment.

KEYWORDS

transformer bushing, leak repair, power transformer, SF6

1. Introduction

The oil-filled large power transformer is still the workhorse of the electric power industry. Even with the advances in the technology of other insulating media, the large oil-filled transformer is still the tried and true major component of the transmission-type electric substation. Additionally, the oil-filled transformer is still the norm when it comes to subtransmission and distribution substations too. The opinion of this author is that many of these transformers were built in the pre-

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computer era with margin factors based upon manual calculations performed by engineers with a built-to-last mentality. Thus, there are many older oil-filled transformers in service throughout the world. Even though they were built to last, they do have their share of old age issues coming to bear. One of the greatest issues is oil leaks. Gaskets on bushings, radiator flanges, pumps, piping etc. are deteriorating and leaking. If oil is leaking out, there is a risk of moisture and air being drawn in via capillary action, compromising the transformer oil insulating qualities.

The classic repair technique is to take the transformer out of service, drain the oil (usually thousands of gallons), remove radiators, remove bushings, etc. Taking equipment out of service for weeks at a time, and utilizing large substation crews, cranes, tankers, vacuum fill-oil processing trailers, etc. can be a costly endeavor. Today's electric utility management is monitoring expenses closely. Transmission operations are wheeling power from far away generation sources to the local utility distribution load centers. Outages on transmission equipment are closely scheduled, and lengthy outages are not granted on short notice for emergent repairs. The operations staff are coming to the maintenance staff asking for other solutions to address these oil leak repairs. The US EPA SPCC Regulations [1] contain stringent requirements for electric utilities to monitor their equipment to prevent oil discharges off their substation properties. Even slight oil leaks, creating stains down the sides of transformers and oil circuit breakers, create a negative perception to the general public that the utility is not maintaining their equipment to a high standard of reliability. Figure 1 illustrates such an oil stain running down the side of a large high voltage power transformer, while oil leaks and stains at the base flange of high voltage bushing pockets can be seen in Figure 2. Oil leak quantities can be great enough to require the use of absorbent material in granular form, such as that applied in Figure 3, or in rectangular oil absorbent pads [2] to contain an oil release to keep it from running into the substation drainage system and potentially running off the station property into the general environment outside the station.

2. Substation leak seal technique

An alternative oil leak repair technique entails a process of addressing the individual oil leaks by means of drilling and injecting sealant compound into the leaking transformer gasket groove on the leaking flange. This technique will work on radiator flanges, pump flanges, piping flanges, as well as injecting into flapper valve

Figure 1. Unsightly oil leaks running down the side of a large power transformer

Figure 2. Oil leaks at the base flange of high voltage bushing pockets

Figure 3. Oil leaks running down the side of a large power transformer and contained with oil absorbent material

Figure 4. Repair being made to a lower level radiator flange by injecting sealant into the gasket groove with the transformer in normal service

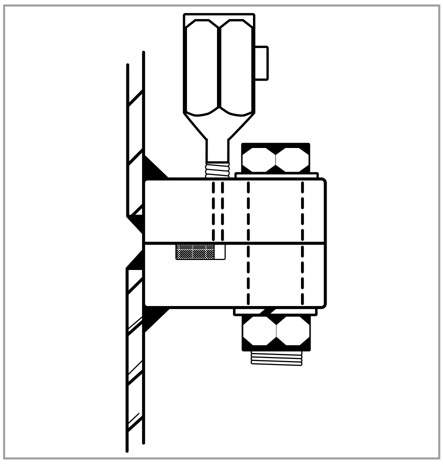

Figure 5a. Sketch depicting the drill and inject nozzle-valve placed to fill the gasket groove of the flange

Figure 5b. Actual injection valve in place

Figure 5c. An injection valve with the hose to the injection tool connected

If oil is leaking out, there is a risk of moisture and air being drawn in via capillary action, compromising the transformer oil insulating qualities

stems. These repair techniques require an initial inspection, usually performed with the transformer in service. Many repairs on the lower end of transformer radiators, and pumps and piping can be performed with the transformer in service. Leaks on the upper end of radiators and bushing flanges usually require an outage for safe work clearances, but can be performed in one or two days.

Similar leak seal techniques have been performed on piping and equipment flanges in refineries, paper mills, and petrochemical plants for years. These leak seal techniques are considered "high pressure" leak repairs, as opposed to "low pressure" leak repairs which are the approach to repairing leaks in electric substation apparatus. The approaches to repairing a high pressure leak and a low pressure leak can be extremely different. Additionally, the sealing compounds used in the various high pressure repairs are many due to the possible reactions between the sealant and the materials being transported in the high pressure piping systems. All leak sealing work on electric substation apparatus can be performed with just one variety of leak sealing compound that does not react adversely with transformer oils, nitrogen, or SF6 gas.

In 1988, a leak sealing technician by the name of John Edmon, who had regularly been doing repair work on piping at a power plant in the western U.S, was asked by the utility's senior equipment specialist if it was possible to apply high pressure leak seal techniques to repairing transformer oil leaks. Following this inquiry, John Edmon worked with an equipment engineer and developed the low pressure substation leak seal technique.

Figure 4 depicts a technician injecting sealant into a gasket groove on a lower level radiator (cooler) flange. This type of leak repair can easily be performed with the transformer still in service. Thus the leak repair is completed in hours versus the days or weeks required to drain the transformer and remove the radiators to regasket the leaking flange.

Figure 5a is a close up sketch of the valve used to inject the sealant compound into a gasket groove. Figures 5b and 5c are actual photos of injection valves in place ready for pumping sealant into a gasket groove. This can be a piping flange gasket groove or a bushing or bushing pocket gasket groove. The common practice is to drill several holes and install several valves around the flange and pump the sealant until the gasket groove is filled, effectively stopping the leak.

3. Techniques for addressing bushing-related oil leaks

3.1 Bushing pockets

Bushing pockets introduce another set of gasketed flanges requiring sealing. Figure 6 shows a common style of bushing pocket. The technique of drilling an access hole to the gasket groove and injecting under pressure the sealant compound into the gasket groove, essentially creating a new gasket without disassembly of the transformer to access the gasket groove. Then the drilled hole is threaded and a plug is inserted to contain the sealant under pressure.

3.2 Bushing flanges

Often the bushing flange is the leaking culprit. If the drill and inject technique cannot be used, the next solution is to fabricate a precision clamp of machined aluminum and utilize the existing bolts to hold the clamp in place. This clamp

The oil leak repair entails a process of drilling and injecting sealant compound into the leaking transformer gasket groove on the leaking flange

Figure 6. High voltage bushing pocket with oil stains running from the transformer top down the side. Note the black material at the top of the pocket, which is most likely an attempt by the utility to stop the leak with an externally applied material.

creates an additional cavity over the leaking flange that can contain the sealing compound under pressure and stop the leak. Figure 7 shows a bushing leaking at the interface between the porcelain and the steel base of the bushing.

Figure 8 shows the precision fabricated aluminum clamp installed around the leaking bushing at this porcelain and steel interface. This clamp becomes the cavity that is filled with the leak seal compound. Figure 9 shows half of the aluminum clamp before the other section is bolted in place, showing also the cavity in the center of the clamp. One can also see the rubber gaskets on the aluminum clamp above and below the leak seal cavity. These gaskets help hold the clamp in place and prevent damage to the bushing as the clamp is bolted into place.

Figure 10 depicts one half of the aluminum clamp prior to mounting around the bushing.

After the clamp is bolted together in place around the leaking flange on the bushing, injection valves, as depicted in Figure 5a, are used to fill the cavity in the clamp. Figure 11 shows a technician pumping the leak seal compound into the clamp. These nozzle-looking valves are removed and threaded plugs are placed into the injection holes to contain the sealant in the cavity.

The repair specialists for performing this work have addressed enough flange leaks on bushing pockets and bushings that they have a library over 100 clamp designs that can be utilized to create the clamp needed. There is a finite number of bushing styles commonly found on current in-service transformers that they often have the di-

Figure 7. High voltage bushing leaking at the interface between the porcelain and the steel base

Figure 8. Close up of a precision fabricated aluminum clamp installed at the base of a high voltage bushing

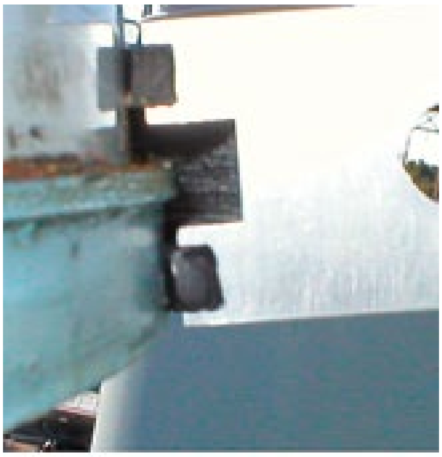

Figure 9. Close up of the inside of a split style aluminum clamp in place on the bushing base

Figure 10. One half of a precision bolted aluminum clamp prior to mounting around a bushing

Figure 11. Technician pumping the leak seal compound into the clamp around the bushing

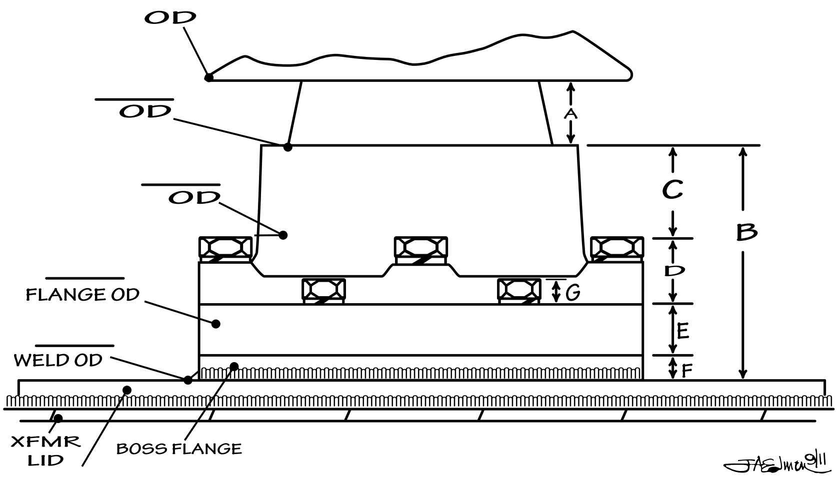

Figure 12. Sample of a measurement diagram that the technicians use to document the dimensions of a bushing for the precise fabrication of a clamp

Some leaks can only be addressed by using fabricated clamps which are machined to a smooth finish with no sharp edges to eliminate any possible corona issues

mensions of the clamp needed on file. Or, they can create a custom clamp based upon their measurements that can be fabricated and express shipped to the work site in a day or two. Figure 12 is a sample of a measurement diagram that the technicians use to document the dimensions of a bushing for the precise fabrication of a clamp. The measurement diagram is sent to the machining fabricator and the clamp is airfreighted to the work site usually the next day for installation.

4. Clamp material

The clamps are usually fabricated from cast aluminum, where molten aluminum is poured into a pattern and core box and finished to precise dimensions to fit the specific component that is leaking. Aluminum is used because of its properties to not corrode in an outdoor environment. This is the same reason aluminum is commonly used in electrical substations for bus bar and live connection details to the apparatus. Occasionally, the leak repair clamps are required in an area that could compromise electrical insulation clearances. These cases call for a clamp made of non-conducting polyvinyl chloride [PVC] material. The PVC enclosures are typically manufactured from four-inch thick PVC plate sheets. Additionally, some repairs could call for a combination aluminum and PVC clamp to maintain the electrical clearances. The reason carbon steel is not used in the fabrication of these clamps is the fact that steel is much heavier than aluminum, and it would take longer to fabricate the components, running up labor costs, plus it rusts and corrodes in the outdoor environment [3]. Figure 13 depicts a bushing with the typical split-type aluminum clamp at the bottom, the common style discussed earlier in this article. Additionally, it shows the threaded style one piece clamp at the top of the bushing. This clamp is designed to fit and thread on the top stud between the top of the bushing and the lead connector pad. All the aluminum clamps are machined to a smooth finish with no sharp edges or points to eliminate any possible corona issues that would be present in a high voltage (138 kV and above) environment.

5. SF6 and GIS installations

SF6 (sulfur hexafluoride) gas is commonly used as a dielectric medium in newer circuit breakers as well as the compact design of substations in congested urban areas throughout the world, where space for electric substations is at a premium. The GIS (gas insulated switchgear) will have

Figure 13. High voltage bushing with a precision aluminum split style clamp at the base as well as a threaded style clamp at the top of the bushing

interconnections with flanges between the switchgear and any transformer bushings required as part of the substation design. The overall view of a GIS to transformer interconnection is depicted in Figure 14a, with a close up image in Figure 14b. This interconnection is essentially a transformer bushing with an SF6-filled environment on the GIS bus side and an oil-immersed bushing on the transformer side.

These leak sealing techniques can be applied to the flanges on the GIS SF6-filled components just as well as on the traditional bushings on oil-filled transformers. The utilization of various custom designed clamps is more prevalently used in the SF6 environment as opposed to the drill and inject technique.

6. Properties of the sealant material

The sealant used by the prevalent leak sealing firm depicted in this article is designed to be of the same durometer properties as the commonly used O-ring and gasket materials used in the flanges on today's transformers and bushings. It has the same ability to expand and contract to facilitate a good seal under all conditions between hot summer and cold winter. The

If the sealant does get into the transformer tank or oil-filled cavity of a bushing, it will not react adversely with transformer oil, nitrogen, or SF6

sealant is formulated with good dielectric and power factor qualities. If the sealant does get into the transformer tank or oil-filled cavity of a bushing, it will not react adversely with transformer oil, nitrogen, or SF6. Thus all repairs can be made with only one type of sealing compound as opposed to having to maintain a stock of multiple types of sealing compound. It is considered to be "technician and customer friendly", meaning it is of such a property for installation (injection) by means of a hydraulic sealant injection gun and cures to the necessary durometer to replicate the gasket material it is replacing [4]. Additionally, the material remains soft and if the repaired component requires disassembly or removal, the cured sealing compound is always soft and pliable. It never hardens. The containment clamp can be removed and the compound cut out with a knife allowing the component to be taken apart. Then upon the assembly the technicians can come back and reinstall the clamp or a new clamp and reseal the leak. The sealant does not stick to the metal surfaces of the transformer, nor leave a residue of any kind. Figures 15a, 15b and 15c show how the sealant compound appears in place around a bushing with the clamp removed. Figure 15d shows the sealing compound cut away from the


Figure 14a. SF6 GIS bus connections to high voltage bushings on top of a transformer


Figure 14b. Close up of the GIS to transformer connections

Figures 15a, 15b and 15c. Three views of a bushing with a portion of a previously installed bolted clamp removed

Figure 15d. Sealing compound cut away from the bushing

This repair technique is extremely cost effective not only in controlling labor and material costs, but also in minimizing outage down time for the apparatus

bushing, depicting how soft and pliable it is. The mesh material in this photo is what is commonly put in place around the porcelain of a bushing to (a) keep the clamp from creeping up the bushing as the sealant is pumped into the cavity in the clamp, and (b) to protect the porcelain from being scratched or chipped. Note that the sealing compound is soft and does not adhere to either the porcelain or the steel. The sealant, having similar properties to the gasket material it is formulated to replace, also has a similar life to that of the gasket materials. The potential benefit of the sealant compound installations is that when the sealant gasket begins to leak again it can be potentially replaced by the same technique as the original repair. The holes drilled, providing access to the gasket groove, can be opened again by removing the threaded plugs, and utilizing an injection valve and hydraulic sealant injection gun to pump sealant in again to stop the leak.

Conclusion

This article describes a specialized technique for repairing oil leaks on bushings and the transformer tank flanges. This repair technique is extremely cost effective not only in controlling labor and material costs, but also in minimizing outage down time for the apparatus. The cost of and effort to prepare a transformer for removing and replacing a bushing is massive compared to taking a brief outage primarily for safety clearance to inject leak seal material into a gasket groove or to install a clamp around a bushing base that is leaking oil. The processes described have been in practice by just a few specialized repair firms in the USA. The techniques have been around long enough to have proven to be both effective in providing a successful repair as well as keeping your maintenance budget under control.

References

[1] US EPA Spill Prevention, Control, and Countermeasure (SPCC) Regulation (40CFR112)

[2] Oil absorbent material in granular form or pads as manufactured by Oil-Dri Corporation of America, Chicago, IL, USA

[3] Information on clamp design and material provided by John Edmon, Technical Director of TDS-Transmission & Distribution Services, Warrenville, IL, USA, www.tdsleakseal.com

[4] Information on the properties of the sealant compound described in this article provided by John Edmon, Technical Director of TDS-Transmission & Distribution Services, Warrenville, IL, USA*

**The formulation of this compound is proprietary and property of TDS-Transmission & Distribution Services. Further details of this formulation may be provided upon request to TDS-Transmission & Distribution Services, www.tdsleakseal.com*

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